TECHNICAL INFORMATION ON BUILDING MATERIALS

FOR USE IN THE DESIGN OF LOW-COST HOUSING

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THE NATIONAL BUREAU OF STANDARDS
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MASONRY WALL RESISTANCE TO RAIN PENETRATION

With a view to obtaining data which may be found of value in reducing the water leakage in masonry walls, the National Bureau of Standards has recently completed tests under the direction of D. E. Parsons, on 113 sample walls of different types of construction. The investigation was planned to obtain information on the effect of the following factors on the permeability of masonry walls:

(a) Thickness, bonding of units, kind of brick of hollow unit, kind of mortar and method of filling joints.

(b) Wind pressure on walls.

(c) Repointing and waterproofing treatments.

All the materials used were representative of those commonly used in building construction. The bricks were selected to cover a wide range in both the rate and amount of absorption for brick used in exposed structures. One type of brick had a very low, one a medium and the third a very high and rapid absorption. These three types are designated in Table 1 as a, b, and c, respectively.

A group of 48 brick walls included specimens both 8 and 12 inches thick, using three kinds of brick (see Table 1), 4 cement-lime mortars and two classes of workmanship in various combinations.

Six different types of structural clay tile and one kind each of stone and cinder concrete block were faced with either stucco or with brick (b). All walls of hollow masonry units (Table 2) were built with a single cement-lime mortar. The five mortars used were designed to determine the relative permeability of walls with high-lime or high-cement mortars; the effect on permeability of integral waterproofing, and of differences in water retaining capacity. Physical properties of these mortars are given in Table 3.

The stucco used as a facing for the 8 walls of tile (j) was mixed in the proportions by weight of one part of Portland cement to three parts of sand; volume proportions were one part cement to about 3.5 parts of loose damp sand. The water added to each batch was about 8.5 gallons per sack of cement. After applying the stucco to the walls they were thoroughly wetted once a day for several days.

Walls of workmanship A were solidly built. The bed joints were spread to a uniform thickness and the cross and collar joints were carefully filled. Face joints were tooled with round steel bars.

Workmanship B was of a type commonly used for contract construction. Interior joints of the wall were open and a minimum amount of mortar was used. Face joints were cut.

After completion, the walls were allowed to stand in the laboratory for two or three days without being moved. The walls were then whitewashed on the ends and back and placed in the drying rooms. After one month or more, depending upon the time required for drying, the walls were given the first permeability test. They were also dried thoroughly between successive tests.

Table 1 - PHYSICAL PROPERTIES OF BRICK

Type	Average dimension			Avg.	Absorption by total immersion			Time required for total penetration by capillary action		
	Width	Length	Depth	dry	5 hr	48 hr	5 hr	Flat	Edge	End
					cold	cold	boil			
					per-cent	per-cent	per-cent	hrs.	hrs.	
(a)	3.75	8.00	2.25	5.21	0.4	0.6	1.6	-	-	-
(b)	3.60	7.75	2.15	4.35	7.7	9.1	11.4	0.40	1.9	12.5
(c)	3.95	8.20	2.30	4.76	15.9	16.8	18.8	0.12	0.52	1.8

Table 2 - PHYSICAL PROPERTIES OF STRUCTURAL CLAY TILE AND HOLLOW CONCRETE BUILDING UNITS

Masonry unit	Dry wt.	Absorption by 24 hrs cold immersion		Absorption by 1 hour boil
	lb.	percent	lb/ft³	percent
(d) Double shell, 6 cells	33.3	2.8	-	3.9
(e) Side construcion, 3 cells	15.8	5.7	-	8.1
(f) Speed-a-Backer	22.5	4.1	-	7.1
(g) Raritile, 4 cells	25.8	10.6	-	14.6
(h) Techwood, 6 cells	33.7	10.4	-	13.3
(j) Standard, 6 cells	34.1	4.1	-	6.3
(m) Stone concrete blocks, 2 cells	29.9	8.9	10.8	-
(n) Cinder concrete block, 2 cell	21.9	16.2	13.3	-

Table 3 - PHYSICAL PROPERTIES OF MORTARS

Mortars	Proportions of cement, lime & sand: By vol.	By dry wt.	Avg. water content percent by wt. of dry mtls.	Compressive strength in 28 days	Flow after suction(1)
				lb/in²	percent
1	1:0.25:3	1:0.11:2.6	19.3	2850	86
2	1:1:6	1:0.42:5.1	22.6	640	95
3	1:2:9	1:0.85:7.7	23.7	250	97
4	1:1:6	1:0.42:5.1	22.7	530	95
5	1:1:6	1:0.42:5.1	19.8	950	30

(1) Water retaining capacity by the method of Federal Specifications SS-C-181a

TESTS

Capillarity test: This was the first test applied to each wall. The wall was supported in a vertical position and water applied near the top of the exposed face by means of a perforated metal pipe, resulting in a thin sheet of water running down the face of the wall. In this test the water penetrated the walls under the forces of capillarity and gravity only.

Heavy-rain test: The conditions of exposure simulated the effect of a wind storm accompanied by heavy rain. The wall was clamped into position so as to form one side of an air-tight pressure chamber, the joint between the wall and the chamber being made air-tight by means of a sponge rubber gasket. The air pressure of 10 lbs/sq ft produced a pressure gradient within the wall from face to back.

Light-rain test: These tests were made only on some of the walls that had been found most permeable in the heavy-rain tests. The test differed from the heavy-rain test only in the amount of water applied and in the method of application, which was by means of atomizers in amounts equivalent to 0.2 in/hr/sq ft of wall surface.

RATINGS

Since it was desirable to classify the walls according to their comparative resistance to penetration by water, an arbitrary system of rating was established. The backs of the walls were not plastered and the high relative humidity in the testing room prevented the drying which would occur on the interior surface of walls in heated buildings. The ratings of the walls were as follows:

Excellent (E): Walls having no leaks through either the wall or the facing withe, and less than 25% of the wall area damp in 7 days.

Good (G): Walls having no leaks through either the wall or facing withe, and less than 50% of the wall area damp in 1 day.

Fair (F): Walls having 50% or more of the wall area damp in 1 day, or having a leakage through the wall or facing of less than 1 litter of water per hour.

Poor (P): Walls having a leakage of less than 1 liter of water per hour through the wall and less than 15 liters of water per hour through the facing during the first day.

Very poor (V.P.): Walls having a leakage of more than 1 liter of water per hour through the wall, or more than 15 liters of water per hour through the facing.

RESULTS OF TESTS ON BRICK WALLS

The results of the wall tests in general were consistent enough to indicate at least the relative advantages or disadvantages of different workmanships, kind or combination of brick, kind of mortar and of wall thickness. Nearly all the walls, on which it was necessary to make repeated tests of the same kind, showed a decrease in permeability.

Comparative performance of all-brick walls under capillarity and heavy-rain tests, with the capillarity test taken as unity, gave the data shown in Table 4.

Additional data from the light rain tests on the more permeable walls indicated that it took about 50 times as long for dampness to penetrate the wall during a light-rain test and about 200 times as long for the appearance of leakage through the facing than was required for the heavy-rain test.

Table 4

Brick	Workmanship and thickness	Relative time for penetration as indicated by: Dampness	Relative time for penetration as indicated by: Leakage	Relative area damp after 1 day	Relative amount of leakage
(a)	8 in. A	0.07	-	1.4	-
	12 in. A	0.25	-	1.0	-
	8 in. B	0.29	0.45	1.1	3.1
	12 in. B	0.14	0.13	1.1	2.7
(b)	8 in. A	0.05	0.01	1.0	3.1
	12 in. A	0.04	-	1.6	-
	8 in. B	0.45	0.21	1.0	3.6
	12 in. B	0.06	0.02	1.3	5.9
(c)	8 in. A	0.54	0.08	1.1	4.0
	12 in. A	0.18	-	1.6	-
	8 in. B	0.30	0.03	1.0	2.9
	12 in. B	0.29	0.05	1.1	4.1

The results of the tests showed that workmanship was the most important factor affecting the permeability of brick walls of common American bond. The best performance was obtained when the interior joints were well filled and the face joints were tooled (workmanship A). Walls with tooled face joints were more resistive than similar specimens with cut joints, but the filling of the interior joints was of greater benefit than tooling of the face joints. In the case of workmanship A, the least permeable walls were those built of the least absorptive brick, whereas the absorptive properties of the brick had little effect on the performance of the more permeable walls of workmanship B.

Varying percentages of lime and cement in the mortar had only a very small effect upon the water permeability. The walls with mortar number 1 (high cement-low lime) were slightly less permeable than those with mortars of greater lime content. The addition of a metallic stearate to one of the mortars (No. 4) had little effect on the permeability. The substitution of a non-plastic lime for the highly plastic putty used in mortars 1 to 4 inclusive, had a much greater effect than changes in the relative proportions of lime and cement. Walls constructed with the 1:1:6 mortar containing non-plastic lime (mortar 5) showed significantly inferior performances to those built with the other mortars. These results indicate that the permeability of the masonry depended much more upon the water retaining capacity of the mortars than upon the lime-cement ratio. The relative working properties of mortars of low and high water retaining capacities were noted by the masons who expressed satisfaction with the working properties of mortars 1 to 4, but who commented on the difficulty of using mortar 5, particularly when laying bricks having a high suction (high absorptive brick in a dry condition).

Wetting high absorptive brick before laying resulted in the construction of walls of much lower permeability than was the case when the brick were laid in a dry condition. The effects of water content or suction of the brick were greatest for workmanship A.

RESULTS OF TESTS ON WALLS WITH HOLLOW STRUCTURAL UNITS

The performance of the walls with a backing of hollow units was affected more by the permeability of the facing than by any other factor. The walls of workmanship B leaked considerably at the bottom and the cells in the lower courses were partially filled with water. However, on the average, the performance of these walls was not much different for typical 12-inch walls of brick and workmanship B. The walls of hollow concrete units were very permeable, irrespective of workmanship.

The walls constructed with two $\frac{1}{2}$-inch facing coats of stucco on a backing of 6-cell 8 x 12 x 12-inch clay tiles were the least permeable of all walls containing hollow masonry units. The data on performance of the stucco walls, in the heavy-rain tests, are given in Table 5.

Table 5 - PERFORMANCE OF WALLS WITH STUCCO FACINGS

(Heavy-rain tests)

Construction of walls (1)	Duration of test	Time to fail as indicated by: Damp through wall	Leak through wall	Area damp at end of test	Max. leakage per hour	Rating
	days	hours	hours	per-cent	liters	
E-p-a	4	87±5	-	55	0	G
E-p-r	3	41±4	-	8	0	G
E-w-s	14	207±5	-	33	0	E
E-w-r	6	64±5	-	33	0	G
S-p-s	6	108±7	-	17	0	E
S-p-r	7	152±7	-	25	0	E
S-w-s	7	142±14	-	10	0	E
S-w-r	6	127±	-	17	0	E

(1) Key for construction symbols:

E - tile set on end. : S - tile set on side.
p - plain stucco. : w - water-proofed stucco
s - smooth texture on finish coat : r - rough texture on finish coat

SURFACE WATERPROOFING TREATMENTS

In order to determine the effectiveness of waterproofing methods for leaky masonry walls in existing structures, several of the walls which leaked in the permeability tests were treated and then retested. Three treatments were used, classified as:

1. Raking the face joints and repointing with mortar.

2. Filling openings in the face of the wall (especially in the joints) with cement-grout or wax.

3. Painting the wall with colorless solution, or oil paint or cement paint.

Some of the treatments were combinations of these and one was a molten paraffin treatment. Repointing of the face joints was successful in that the permeability of all the walls was greatly reduced. The permeability of the brick (c) walls was not reduced as much, because the repointing operation did not affect the absorptive properties of the brick.

The use of colorless waterproofing solutions containing paraffin with tung oil or aluminum stearate had little effect on the permeability

of walls that leaked through openings in the joints. These solutions were somewhat effective when used on walls that had been penetrated by moisture through capillary attraction.

Two kinds of joint filling materials were used; a wax, and finely divided cementitious mixtures. The performance of the walls was improved by waxing the joints, the average rating being increased two grades from V.P. to F. The paraffin wax in the joints altered (and possibly marred) the appearance of the walls because of irregular accentuation of the joints. Grouting of joints with a mixture of 40% high-early-strength cement; 15% powdered flint, and 45% Potomac River building sand greatly reduced the permeability of the walls.

Painting of the exposed surface of walls with either oil or cement paints was markedly effective on walls that had previously been very permeable, irrespective of whether the water had penetrated the walls through openings in the joints or by capillary action. Cement paint applied to walls of concrete masonry units (workmanship A) raised the rating of these walls from very poor to good.

CONCLUSIONS

Workmanship affected the permeability of the walls more than any other factor. Walls with tooled joints were less permeable than similar walls with cut joints; but the quality of the workmanship within the walls had a greater influence than the kind of surface finish on the joint.

The effect of wall thickness on the relative permeability of 8-inch and 12-inch brick walls was such that it required several hundred times as long for moisture to penetrate the thicker walls of workmanship A, and six times as long for the penetration of 12-inch walls as for the 8-inch walls of workmanship B.

The absorptive properties of the brick had a greater effect on the permeability of walls of workmanship A than on walls of workmanship B. The least permeable walls of workmanship A were those built with the low absorptive brick. Walls built with high-cement, low-lime mortars were slightly less permeable. The use of a lime of low plasticity producing a mortar with low water retentivity greatly increased the permeability of the walls. This effect was more pronounced when the mortar was used with high absorptive brick. Wetting high absorptive brick before laying reduced the permeability of the walls, especially for workmanship A.

Walls with a brick facing and a backing of hollow units were about equally as permeable as all-brick walls of similar workmanship.

Walls with a structural clay tile backing and a stucco facing were less permeable than walls faced with a medium absorptive brick.

All of the joint treatments such as repointing, grouting, or filling the joints with a paraffin wax were effective in stopping leakage through openings in the face joints. The appearance of walls was altered and possibly marred by the paraffin wax in the joints. Molten paraffin, oil paint and cement paint were effective waterproof coatings.

DURABILITY OF BUILDING MATERIALS

TIBM 59 and TIBM 60

The investigations relating to the durability of some loose-fill and aluminum foil insulating materials, and the corrosion of ferrous metals used in house construction were undertaken at the National Bureau of Standards primarily for the guidance of Federal agencies engaged in housing.

In order to afford adequate time for review of the facts and to bring the investigations to a final conclusion, the tentative reports (TIBM 59 and TIBM 60) relating to the preliminary studies are being withheld from general distribution.

However, the investigations of the properties and suitabilities of various types of building materials, including those outlined in TIBM 59 and TIBM 60, are being carried on actively at the National Bureau of Standards, and the results of these investigations will be made available in permanent form as soon as the various stages of the work can be completed.

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